

Eclipsing Binaries Showing Light-Time Effect

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ABSTRACT

Four eclipsing binaries which show apparent changes of period have been studied in case of possible presence of the light-time effect. With the least squares method we calculated new light elements of these systems and mass function of predicted third body and its minimum mass. We discussed probability of a presence of such bodies in case of mass function, changes in radial velocity and third light in solution of light curves, respectively.

Keywords: eclipsing binaries, period variations, O-C diagram analysis.

1. Introduction

Light-time effect (hereafter LITE) in eclipsing binaries, caused by the orbital motion of the eclipsing pair around the barycenter of the triple system, produces period variation in minima timings. It was explained by Irwin in 1959 and its necessary criteria have been mentioned by Friebos-Conde & Hertzeg in 1973. They are following: agreement with a theoretical LITE curve, secondary minima behave identically with primary ones, reasonable value of the mass function and corresponding variations in radial velocity, respectively.

We found, that most of the necessary criteria listed above are satisfied in all systems presented below. Their $O - C$ diagrams are also presented. The curves represent computed LITE versus epoch. The individual primary and secondary minima are denoted by dots and circles, respectively. Larger symbols correspond to the photoelectric or CCD measurements which were given higher weights in our computations. All data were found in published papers.

2. Observations

AR Aur (HD 34364) as a variable was discovered in 1931. For the computations here we use only accurate photoelectric and CCD minima timings. From these data we have calculated new light elements

$$\text{Min I} = \text{HJD } 24\,27887,7299 + 4,13466577 \cdot E.$$

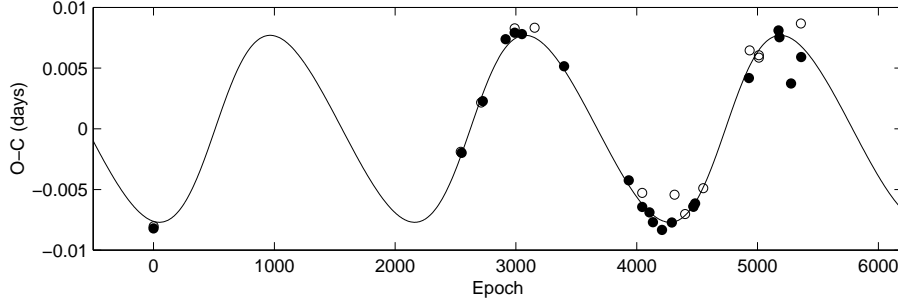


Fig. 1.— The O-C diagram of AR Aur.

The period investigation in 1988 was made by Chochol et al. With new minima timings we were able to determine third body orbit with more plausibility. Because of the relative low mass of the unresolved component, the third light must be less than 1 % of the total light. Also the variations in radial velocities, because of the low mass and errors in velocity measurements, are nowadays still inconclusive.

R CMa is one of the most exemplary eclipsing binary system which show LITE. Almost 300 minima times of R CMa (HD 57167) were collected. Our computations with these data lead to new light elements

$$\text{Min I} = \text{HJD } 24\,45391,2570 + 1^{\text{d}}13594210 \cdot E.$$

We can discuss our results with system analysis from Ribas et al. (2002), who calculated lower p_3 but higher semiamplitude, which gives higher mass function. Variations in radial velocities and also astrometric confirmation from Hipparcos satellite is still inconclusive. The third body is probably WD or M-type dwarf.

FZ CMa. Moffat and Vogt performed detailed spectroscopic and photometric study of FZ CMa (HD 52942) in 1983, but period investigation was realized only with minima from 1973 to

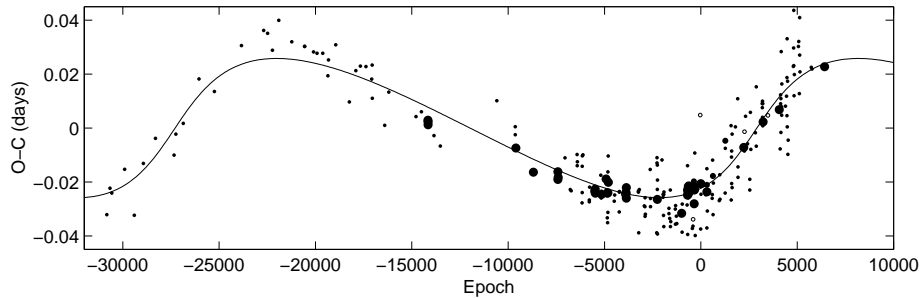


Fig. 2.— O-C diagram of R CMa

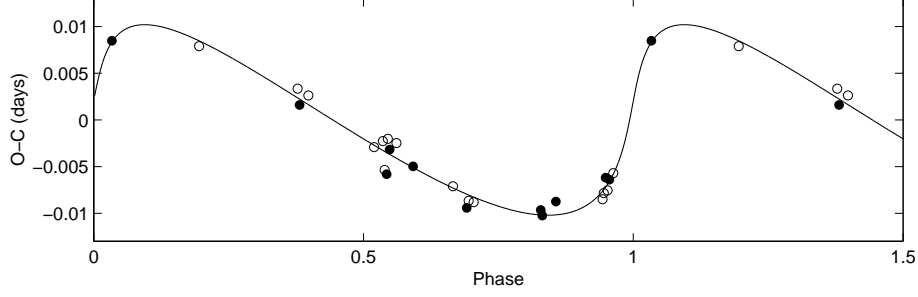


Fig. 3.— The O-C phase diagram of FZ CMa.

1980. New light elements are

$$\text{Min I} = \text{HJD } 24\,41743,5915 + 1^{\text{d}}.27303611 \cdot E.$$

As we can see in Table I, minimum mass of this body is very high and in very eccentric orbit, so in the system would dominate, what seems unlikely. Possible solution is, that the third body is a binary too, what seems likely and nearly corresponds to the spectral analysis.

TX Her (HD 156965) as a variable was found by Miss Cannon (see Pickering 1910). It was very often observed, what leads to large list of visual minima times and from 40's to accurate photoelectric and CCD ones, which leads to new light elements

$$\text{Min I} = \text{HJD } 24\,40008,3686 + 2^{\text{d}}.05980975 \cdot E.$$

We can compare our results with the latest LITE study of TX Her by Ak et al. (2004), who calculated higher value of excentricity, and semiamplitude, and lower period p_3 , so their mass function is nearly double than our.

In table below are M_i masses of components, p_3 period of the third body, A semiamplitude of LITE (see e.g. Mayer 1990), e excentricity, ω length of periastron, $f(M_3)$ computed mass function

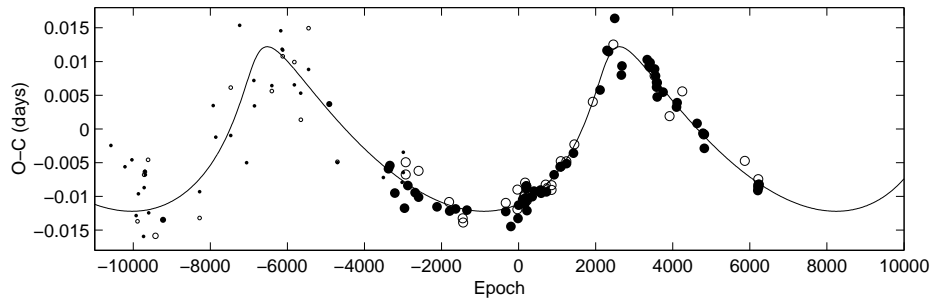


Fig. 4.— The O-C diagram of TX Her

and $M_{3,min}$ minimum mass (for $i = 90^\circ$) of this predicted body, respectively.

Table 1: The results for four studied LITE systems.

Name of star	Spectrum	M_1	M_2	p_3	A	e	ω	$f(M_3)$	$M_{3,min}$
		$[M_\odot]$	$[M_\odot]$	[years]	[days]		[deg]	$[M_\odot]$	$[M_\odot]$
AR Aur	B9V+B9.5V	2.48	2.29	23.92	0.0077	0.209	2.3	0.0044	0.497
FZ CMa	B2.5IV-V+B2.5IV-V	5.40	5.30	1.511	0.0102	0.794	7.0	10.338	22.51
R CMa	F0V+K2IV	1.07	0.17	93.89	0.0258	0.498	357.8	0.0155	0.338
TX Her	A7+F0	1.62	1.45	51.53	0.0122	0.654	48.6	0.0048	0.387

3. Conclusion

We have derived new LITE parameters for four eclipsing binaries by their $O-C$ diagram analysis. But for the final decision of the presence of LITE we need further accurate timings of minima or appropriate confirmation by another method (radial velocity variations, third light in a light curve analysis or astrometric observations).

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